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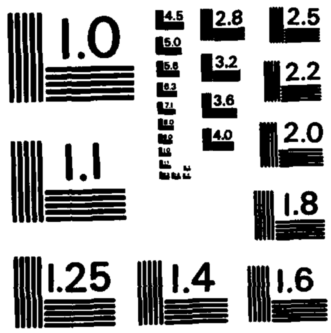

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FOREIGN TECHNOLOGY DIVISION

FUNCTIONING OF A METAL-DIELECTRIC-SEMICONDUCTOR-METAL STRUCTURE WITH ELECTROOPTICAL READING IN THE GAS-LASER INFORMATION WRITE/ERASE MODE

by

N.G. Basov, V.N. Batog, et al

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Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
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М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

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FUNCTIONING OF A METAL-DIELECTRIC-SEMICONDUCTOR-METAL STRUCTURE WITH ELECTROOPTICAL READING IN THE GAS-LASER INFORMATION WRITE/ERASE MODE

N. G. Basov, V. N. Batog, I. N. Kompanets, A. Ye. Krasnov, V. V. Nikitin, G. M. Safranov and V. A. Stepanov.

The fabrication and study of an MDPDM [metal-dielectric-semiconductor-dielectric-metal] structures with optical reading are of considerable interest from the standpoint of their application as storage devices for parallel processing of data, and also as highly sensitive receivers and converters of luminous radiation. It is a known fact [1] that the structure - metal—dielectric—highly resistive semiconductor - has the ability to memorize the effect of the external sources of ionization, accumulating the free charge carriers in the region near the electrode. In this case it is necessary to apply electrical voltage to the structure, under the effect of which the carriers drift to the semiconductor-dielectric interface, creating a surface charge thus shielding the field within the semiconductor. Thus, the optical signal (image) is recorded. Optical reading, which does not obliterate the recorded information, can be accomplished by long-wave radiation, for which this semiconductor is transparent, for example, due to the electrooptical effect [2, 3]. This work deals with the dynamics involved in the recording and erasure of information by a coherent light of an He-Cd laser for an asymmetric structure based on a photosensitive electrooptical $Bi_{12}SiO_{20}$ crystal [4].

The structure consisted of a plane-parallel, (100)-plane oriented $Bi_{12}SiO_{20}$ plate of the thickness d_n=150 μm with a reflective silver electrode applied to one side and also of an insulating film and a transparent conducting SnO_2 layer on a quartz backing on the other side of the plate. The F32L polymer of the thickness d_a=5 μm ensured the necessary insulating properties; it withstood the electrical fields $E \sim 10^6$ V/cm and was transparent over a wide range of the spectrum. The photosemiconductor used had the dark resistance $\rho \sim 10^{13}$ Ω·cm and the absorption coefficient K in it was 80 cm^{-1} at the recording wavelength of 0.44 μm. Continuous focusing of the crystal's position was accomplished by the radiation of an He-Ne laser (λ=0.63 μm) utilizing the Pockels effect in a system with reflection [3], which compensates for the optical activity of $Bi_{12}SiO_{20}$. The half-wave voltage determined for it was equal to 5.1 kV. Taking into account the dielectrical parameters of the film (ε_a=2) and crystal (ε_n=40), in the absence of illumination the applied voltage (0–500 V) propagated through the structure with the ratio $U_n/U_a = \varepsilon_a d_n/\varepsilon_n d_a = 1.5$.

The oscillograms shown in Fig. 1 illustrate the dynamics of field shielding in the semiconductor during recording of information. In the absence of an He-Cd laser pulse, the shape of the pulse of the electro-optical response basically iterates the shape of the field pulse then the field pulse is fed to the structure (Fig. 1a). The observed drop in the response amplitude is explained by the self-shielding effect of the field in the crystal by the equilibrium carriers, and also by the free carriers formed under the effect of an external field and red illumination. When the light pulse is switched on (Fig. 1b), the response signal decreases due to shielding of the field within the semiconductor. The degree and time of shielding are determined by the number of initiated carriers, i.e., by the intensity of light. With the density of the luminous flux I~10 mW/cm incident onto the semiconductor, complete shielding was observed at the voltages U up to 200 V (U_n=120 V) on the structure. The period of complete shielding of the field, attained in this case, was $5 \cdot 10^{-4}$ s. From this, the power sensitivity of the given structure is estimated at $5 \cdot 10^{-6}$ J/cm^2 or $4 \cdot 10^{-8}$ J/cm^2·V with λ=0.44 μm. The last estimate is more universal. Let us also calculate the number of carriers necessary to shield the field U_n=120 V. If we designate the density of the surface charge at the semiconductor-

dielectric interface in terms of σ_s, then, after integrating the Poisson equation, we obtain

$$\varepsilon_{\text{д}} E_{\text{д}} - \varepsilon_{\text{п}} E_{\text{п}} = 4\pi\sigma_s, \qquad (1)$$

and then

$$U_{\text{п}} = (U\varepsilon_{\text{д}} d_{\text{п}} - d_{\text{д}} d_{\text{п}} \sigma_s 4\pi)/(\varepsilon_{\text{д}} d_{\text{п}} + \varepsilon_{\text{п}} d_{\text{д}}). \qquad (2)$$

Hence the necessary density of the charge

$$\sigma_s = U\varepsilon_{\text{д}}/4\pi d_{\text{д}}. \qquad (3)$$

and the number of charges $n_s = \sigma_s/e = 0{,}4 \cdot 10^{12}$ (here e is the charge of an electron).

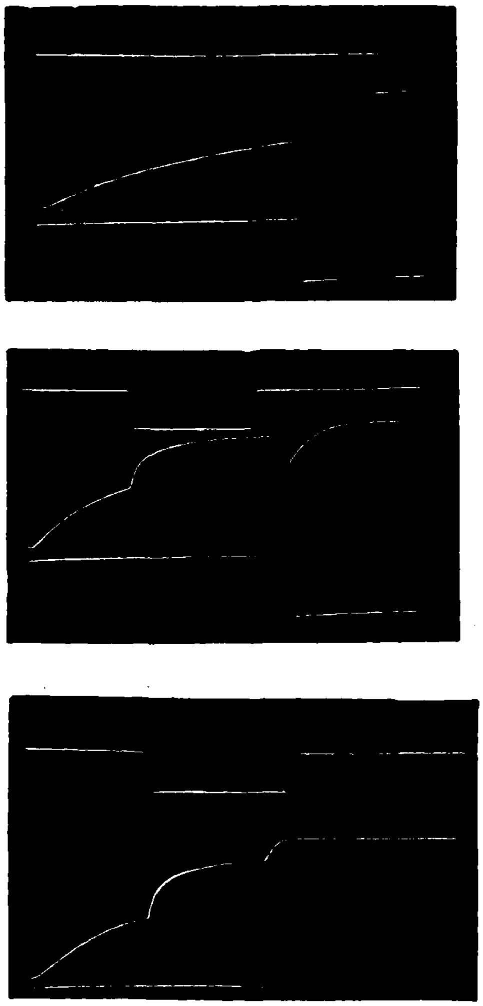

Fig. 1. Dynamic of structure's performance: a) no light pulse, b) recording of information, c) erasure of information. Lower beam is the electric-field pulse (U=200 V), upper beam - pulse of an He-Cd laser lasting 10 ms ($I \sim 4$ mW/cm^2), and middle beam - electrical-response signal (relative units).

Using the oscillograms taken at voltages 0—200 V at the MDPM [metal-dielectric-semiconductor-metal] structure, we determined the field-shielding time $\tau_{\text{экр}}$ as a function of the degree of illumination of the semiconductor I (see Fig. 2). The speed of data recording is

determined by the speed at which the surface charge σ_s is formed by a flow of free carriers from the semiconductor volume

$$d\sigma_s/dt = j_n = en\mu(E_0 - \alpha\sigma_s), \qquad (4)$$

where n is the concentration of free carriers, μ - mobility of the carriers, and $\alpha = 4\pi d_д/(\varepsilon_д d_n + \varepsilon_n d_д)$ is introduced on the basis of (2). Assuming that the recording time is greater than the effective lifetime of the carriers $\tau_{эфф}$ and that $\Delta n \gg n_o$, where n_o is the concentration of the equilibrium carriers, we obtain

$$\tau_{эксп} = (\alpha e\mu\beta kI\tau_{эфф})^{-1}, \qquad (5)$$

since $\Delta n = \beta kI\tau_{эфф}$ (here β is the quantum yield). We have $\tau_{эксп} \sim I^{-1}$, which is in agreement with the experimental result for the time periods that are greater than $5 \cdot 10^{-4}$ s. For shorter periods $\tau_{эксп}$, attained with the radiation density above 10 mW/cm^2 there is a transition to the dependence $\tau_{эксп} \sim I^{-1/2}$, which is characteristic for the case $\tau < \tau_{эфф}$. The determination of the photoresponse also yielded a value of the effective lifetime of carriers for this material - $\sim 3 \cdot 10^{-4}$ s.

On the basis of the experimental results it is possible to estimate the mobility of the carriers. On the basis of (5) and assuming that β=0.1, we find that $\mu = (\tau_{эксп}\alpha e\beta kI\tau_{эфф})^{-1} = 2 \cdot 10^{-3}$ cm/V·s. Such a value of mobility is apparently connected with an insufficient purity of the material - $Bi_{12}SiO_{20}$ (99.99%).

When the light pulse is cut off in the presence of an electric field, the surface charge at the semiconductor-dielectric interface dissipated completely in the period of time ~20 s. The nature of change occurring in the charge recorded on the basis of change in the electro-optical response on an oscillograph with afterglow is depicted in Fig. 3 (curve 1). Curve 2 is a logarithmic function of curve 1 and indicates the existence of several recombination periods ($\tau_{1,2,3}$), which are connected with the existence of the various surface traps.

The use of the MDPDM structures as storage elements requires on-line erasure of the recorded information. On the structure being considered, it was accomplished also by radiation of an He-Cd laser. The oscillogram in Fig. 1c depicts the dynamics of the erasure process during the removal of the electric field from the structure. The erasure time depends on the intensity of light, since it is determined by a

flow of generated carriers, which drift to the field of the surface charge. Since the information erasure and recording processes are of the same nature, the reasure time will not be greater than the recordign time. Nevertheless, the readiness of the structure for a new cycle

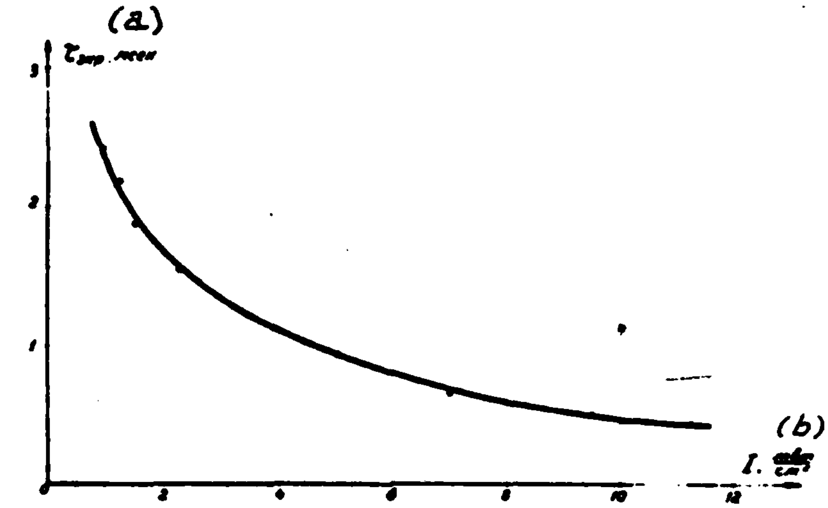

Fig. 2. Recording time as a function of intensity of the exciting radiation. KEY: (a) ms (b) $\frac{mW}{cm^2}$

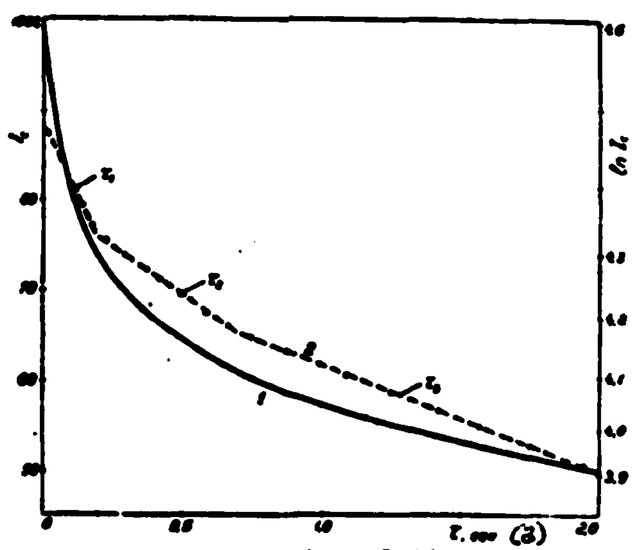

Fig. 3. Time characteristic of the structure's "memory": 1 - change in the electrooptical-response signal; 2 - logarithmic graph of curve 1. KEY: (a) s

of recording will apparently be determined by the effective lifetime of the carriers within the volume of the semiconductor.

The results obtained in this work can be considered reassuring.

Furthermore, they make it possible to plot the course for further investigations. In conclusion the authors thank O. Ya. Maysuradze, S. I. Sagitov, P. D. Berezin, and A. A. Vasil'yev for their assistance in this work, and also N. F. Kovtonyuk, V. A. Morozov, I. A. Poluektov, and A. S. Semenov for the useful discussions.

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